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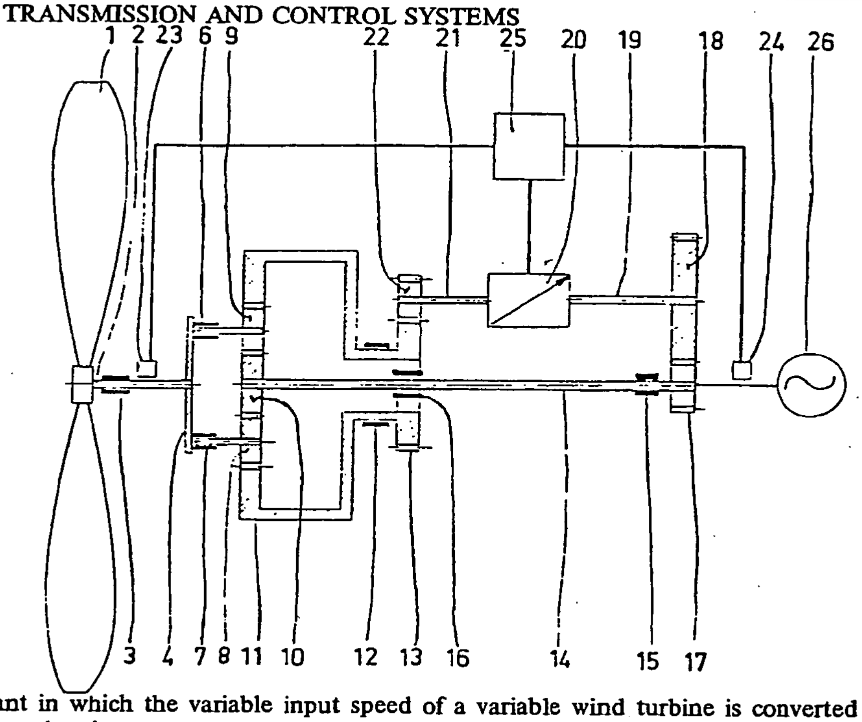

(57) Abstract

A wind-power plant in which the variable input speed of a variable wind turbine is converted to a substantially constant output speed of an electric generator comprises a speed holding system arranged between the output shaft (2) of the wind turbine (1) and the input shaft of the generator (26). This speed holding system includes at least one speed variator (20) connected to a signal processing device (25). The variator (20) is connected, via a variator shaft (21), to a first gear (22) of a planet gear arrangement. The first gear (22) meshes with a second gear (13) which is fixedly connected to a gear ring (11). This gear ring (11) is fixedly connected to the output shaft (2) of the turbine (1), the arrangement being such that in the event of a change in wind speed, the rotational speed of the generator input shaft is maintained constant as the blade-pitch is changed in response to said change in wind speed.

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WINDMILL TRANSMISSION AND CONTROL SYSTEMS

Wind-power plants preferably include synchronous or asynchronous generators whose design requires the rotary speed of the windmill blades to be substantially constant, within very narrow limits. Since wind speeds are rarely constant, but vary as a result of gusts and squalls, very high requirements are placed on the turbine and on the transmission and gearing between the turbine and the generator.

To enable the plant to adapt to prevailing wind conditions, the turbine blades of horizontal-shaft wind turbines are preferably such as to enable them to pivot or rotate about their respective long axes, i.e. have automatic blade-pitch change. In the case of large windmills, considerable inertia forces must be overcome when changing the blade-pitch, mainly due to the blade mass.

This change in blade-pitch by rotating said blades about their long axes is normally effected with the use of mechanical or hydraulic machinery assisted by the force of the wind against the blades, to which latter end the aerodynamic centre of respective blades is offset from the centre of rotation of the blades.

Because, however, of the high inertia forces which must be overcome when changing the blade-pitch, it has been found impossible to prevent disturbances from propagating through the machinery and affecting the synchronous rotary speed of the generator. Such disturbances, can not be tolerated, inter alia because they are reflected in the electric network fed by the plant. Consequently, in addition to changes in the blade-pitch it has been necessary to introduce technical solutions by which a soft coupling can be had between the turbine and the generator. The plant machinery can also be subjected to shock loads as a result, for example, of the generator short circuiting. In conventional constructions, the machinery as a whole is therefore suspended for rotation on a spring unit. When taking into account the considerable dimensions of the machinery

of a large wind-power plant, it will be realized that such an arrangement is both complicated and expensive.

Those skilled in this art are agreed that a horizontal-shaft, few-bladed turbine is one of the best wind turbine designs.

Figure 1 is a diagram showing with a full line an example of a characteristic curve of the aerodynamic efficiency of a propeller as a function of the fast-speed number $\lambda = Rw/_{v}$, where Rw = the trip speed of the propeller and v = the wind velocity, and with a broken line a curve representing an ideal wind turbine. It will be seen from the full-line curve in the diagram that the ideal fast-speed number of the propeller gives an efficiency of about 70%.

For a wind turbine to produce the highest possible energy output, it must operate with a fast-speed number that is always close to the optimal λ. This means that the speed at which the turbine blades rotate must vary.

In order to enable a variable speed turbine to be connected to, for example, a synchronous generator, which requires a constant rotary speed, means for regulating the turbine speed hydrostatically, mechanically and electro-magnetically have been tried. It has been found, however, that the efficiency of these speed-regulating systems is so poor that practically the whole of the additional energy gained through the use of a variable speed turbine is utilized.

When synchronizing a synchronous generator (alternator) with an electric network, there is required a synchronous generator speed, a nominal open-circuit voltage and a correct phase position. The rotary speed of large wind-power plants known hitherto is controlled or regulated solely by changing the blade-pitch. Because of the unavoidable inertia of the system, this means that the task of synchronizing a synchronous generator with an electric network is both time consuming and troublesome.

An object of the present invention is to provide a wind-power plant in which the aforementioned problems are

substantially eliminated. By means of the invention, the rotational speed of a generator can be kept synchronous within narrow limits at the same time as the rotational speed of the wind turbine is adapted to that fast-speed number of the turbine in question which is the optimal in every position. The efficiency of the plant is high, because the major part of the power is transmitted via the mechanical part of the transmission. This is a considerable improvement in efficiency compared with those solutions to the problem of speed control previously proposed.

By means of the invention, the transmission obtains an elasticity which can readily be given any desired characteristic. Such additional arrangements as the sprung suspension of the gear housing, etc., then become unnecessary.

Synchronization of the generator with an electric network can be effected in a quick and easy fashion, since the synchronous rotational speed of the generator is reached earlier than the effect of a change in blade-pitch on the generator speed.

In addition to these advantages, the machinery, without additional arrangements, can be rotated slowly, which is of great value when inspecting and test-running said machinery. The invention can be applied with both horizontal-shaft and vertical-shaft wind-power plants. In the case of vertical-shaft wind turbines with fixed turbine blades, the invention provides for a considerable increase in the yearly power output.

An exemplary embodiment of the invention is illustrated schematically in Figure 2. In the Figure there is shown a propeller 1 comprising, in the illustrated embodiment, blades which can be pivoted or rotated about their respective long axes by known control means not shown. The propeller 1 is connected to a shaft 2 which is journalled for rotation in a bearing 3. Fixedly connected to the shaft 2 is a yoke 4 having at respective ends thereof bearings 6 and 7 for planet gears 9 and 8 respectively. The planet gears 8 and 9 mesh with a sun gear 10 and a gear ring 11.

The gear ring 11 is mounted for rotation in a bearing 12 and is connected on the other side of the bearing with a gear 13. The sun gear 10 is fixedly connected to a transmission shaft 14 which is carried by bearings 15 and 16. Connected to the end of the shaft 14 remote from the bearing 16 is a gear 17 which meshes with a gear 18. The gear 18 is fixedly connected to the input shaft 19 of a speed variator 20. The speed variator is of a kind known per se and may comprise a hydrostatic transmission which includes a variable-displacement hydraulic pump and a hydraulic motor, which by way of an alternative may conversely be driven as a motor or a pump, or said variator may be a mechanically or electrically operating speed variator. The output shaft 21 of the speed variator 20 is fixedly connected to a gear 22 which meshes with the gear 13. A transducer 23 indicates the rotational speed of the turbine, while a transducer 24 indicates the rotational speed of a generator 26. Signals from the transducers are processed in a known manner in a control means 25, which is arranged to send command signals to the speed variator 20.

The described gear box is of a known planet-gear design. It is characterized in that the rotational speed of the gear ring of said planet-gear system is controlled by the output speed of the transmission via a speed variator. By suitable dimensioning of the transmission, the major part of the power transmitted is transfered over the mechanical part of the transmission, resulting in a high efficiency.

The described transmission enables the speed of the turbine to vary within well defined limits while still obtaining a constant transmission output speed so as to enable a synchronous generator to be used.

Figure 3 illustrates an efficiency curve which is normal for the kind of transmission described. It will be seen from the Figure that the transmission has a maximum efficiency at the rotational speed n_o of the propeller or turbine. At n_o the whole of the power is transmitted as mechanical power. At speeds beneath n_o a part of the power

which increases with decreasing rotational speed is fed back to the gear box.

At speeds above n_o part of the power which increases with increasing speed passes through the speed variator. By setting the rated speed n_o of the transmission so that it coincides with maximum efficiency, it is possible to obtain a 10% increase in the yearly energy.

The described embodiment is not restrictive of the invention, but can be modified within the scope of the claims.

Conveniently, the speed variator is driven from the secondary side of the transmission and that the speed can be converted in the variator and caused to influence the total transmission ratio, so that said ratio becomes greater or smaller than a nominal transmission ratio. Further, the variator 20 may be an electric motor which is supplied from an external source, e.g. from the network fed by the generator 26.

CLAIMS:

1. A wind-power plant comprising a substantially mechanically functioning transmission for converting a variable turbine input speed to a substantially constant output speed, whereat the turbine speed is constantly adapted to that fast-speed number which provides maximum efficiency under the influence of a speed variator which when the turbine speed is lower than a nominal speed re-feeds part of the power back to the transmission, said part increasing with a decrease in speed, and at a speed which is higher than a nominal speed transfers an increasing part of said power through the variator, characterized by at least one speed variator (20) having connected thereto a shaft (21), a gear (22) in mesh with a gear (13) fixedly connected to a gear ring (11).

2. A plant according to claim 1 comprising a speed variator (20) which comprises a hydrostatic transmission comprising two main units constructed for variable re-settable displacement, characterized in that each of said units can operate as a driving unit or a driven unit.

3. A plant according to claim 1 including a speed variator (20), a transducer (23) for indicating turbine speed and a transducer (24) for indicating output speed, and a control means (25) for processing signals from said transducers and for sending command signals to the speed variator, characterized in that momentarily occurring disturbancies in the operational speed of either the turbine or said output shaft are prevented from propagating through the transmission by means of the speed variator.

4. A plant according to claim 1, including at least one speed variator (20), characterized in that the speed variator is arranged to convert variations in turbine speed to a constant generator speed when synchronizing a generator (26) with an electric network.

5. A wind-power plant according to claim 1, comprising a variable-speed turbine having an output shaft; an

electric generator having an input shaft connecting with said turbine output shaft; coupling means connecting said turbine output shaft with said generator input shaft; first sensing means operative to sense the rotational speed of said turbine output shaft; second sensing means operative to sense the rotational speed of said generator input shaft; signal processing means for receiving and processing signals produced by said first and second sensing means; said coupling means comprising speed holding means operative to increase or decrease the rotational speed of the turbine output shaft in a manner such that said speed coincides with that fast-speed number which provides the maximum efficiency, characterized in that said speed holding means (20,21) comprises at least one speed variator (20) connected to said signal processing means (25); a planet gear arrangement which includes a first gear (22) connected to said variator through a variator shaft (21); a second gear (13) which meshes with said first gear (22); and a gear ring (11) which is fixedly connected to said second gear (13) and which is also connected to the output shaft (2) of said turbine, said variator shaft (21) together with said variator (20) being operative, in the event of changes in wind speed, to maintain the rotational speed of the generator input shaft constant as the blade-pitch is changed in response to said change in wind speed.

6. A plant according to any one of the preceding claims, characterized in that said variator (20) is a variable electric motor arranged to be supplied from an external current source.

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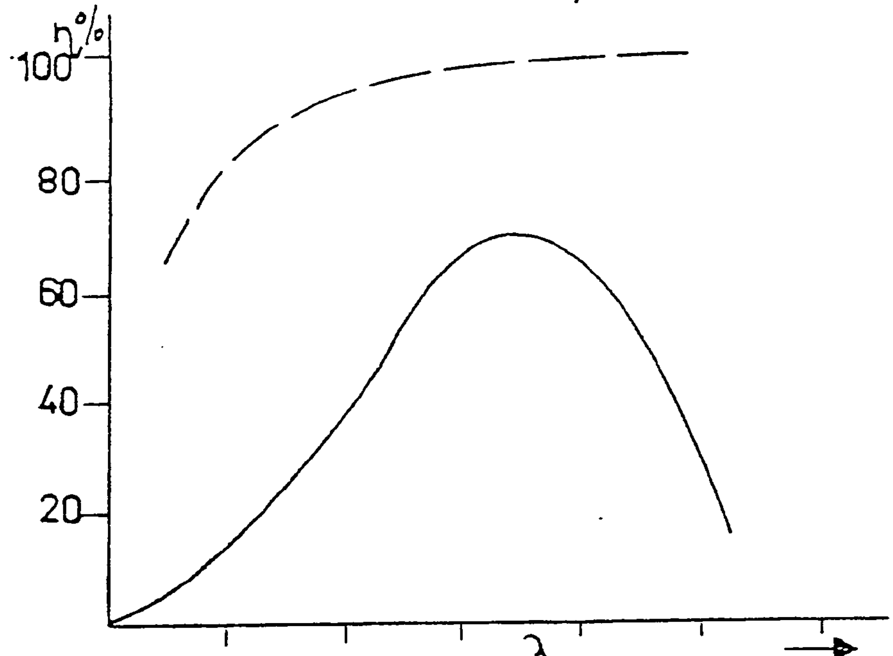
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fig.1

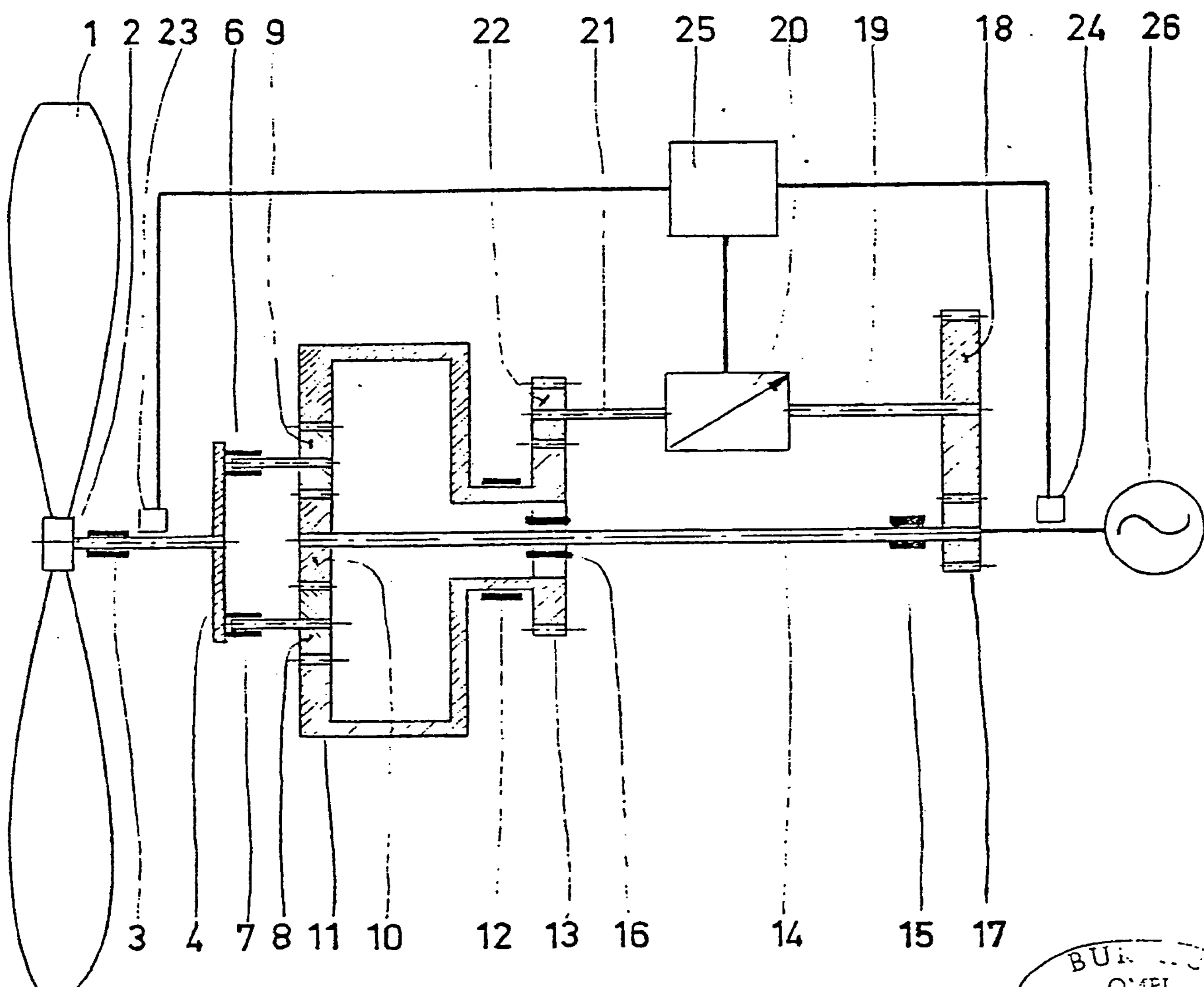
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fig.2

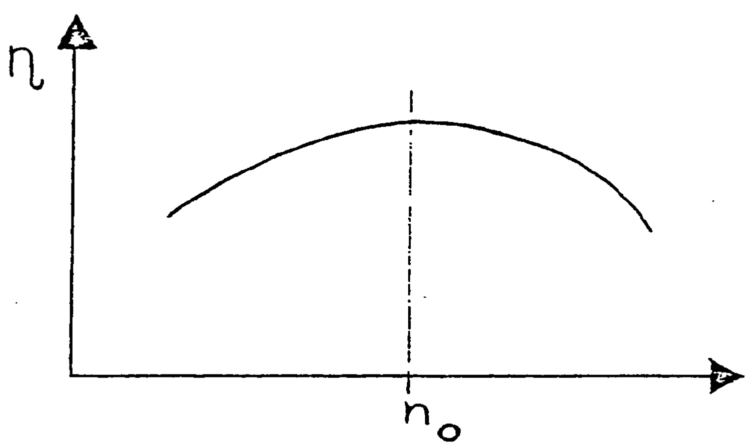

fig. 3

INTERNATIONAL SEARCH REPORT

International Application No PCT/SE80/00283

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC 3

F 03 D 7/02

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System	Classification Symbols
IPC 3	F 03 D 7/02
National Cl	88:2/06
US Cl	290:44, 55

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [5]

SE, NO, DK, FI classes as above

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category *	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
A	DE, C, 2 623 233 published 1977, August 11, Messerschmidt-Bölkow-Blohm GmbH	

* Special categories of cited documents: [15]

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IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [2]
1981-02-20	1981-02-26
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